FURTHER STUDIES OF FABRIC DUST COLLECTORS

by

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I. Introduction

In conjunction with studies on commercial dust collectors, this laboratory has conducted performance tests on a Simon Suction Filter (Entoleter) furnished by the Safety Car Heating and Lighting Company, Inc., (Entoleter Division). Arrangements for the loan of this device (originally manufactured in Great Britain) were made through the New York Operations Office of the Atomic Energy Commission.

The Entoleter unit is a multicompartment bag collector employing cyclic automatic rapping (assisted by back-flow air) to keep bag pressure losses within a limited range to insure a nearly constant air handling capacity. The collector was intended primarily for use in the flour milling industry and has a filtration capacity of ten cubic feet per minute per square foot of cloth.

The purpose of tests conducted by this laboratory were to determine performance characteristics of the Entoleter unit on fine aerosols, i.e. talc and fly-ash, 2.5 and 16 microns mass median diameter respectively, when operated at rated capacity (10 cfm/sq.ft.).

Comparison of test data with that obtained from a Hersey reverse-jet collector operating with similar aerosols and filtration velocities permits better evaluation of the efficiency and pressure loss characteristics of the Entoleter unit. No data has been published (except preliminary data in NYO 1586 (3)) on the Entoleter collector with dusts whose sizes are in the range 1.0 to 20 microns. The performance of the reverse-jet filter has been discussed in several AEC reports (1,2,3,4) and by Caplan (5,6) and Mason (7).

The results of tests on the Entoleter collector do not indicate performance of cyclicly cleaned multicompartment units used industrially at usual low filtration velocities (1 to 3 fpm).

II. Description and Operation

A. Entoleter Unit

The Entoleter unit tested has four compartments connected on the bottom to a common inlet header and hopper, and on the top by means of individual dampers to a common outlet header. Each compartment contains eight sateen weave cotton bags six feet long and eight inches in diameter (100 sq. ft. of cloth). The bags are attached at the bottom to a manifold plate and at the top to a frame. The manifold and frame are connected rigidly together by rods so that when a section is rapped the bags are lifted and dropped (about 1 1/2 inches) as a unit, thus preventing distortion or collapse of the filter tubes. The dampers at the top of the unit connect to the lifting gear so that when a compartment of bags is rapped, primary air flow to the fan shuts off and the compartment vents to atmosphere permitting a current of back-flow air to assist the rapping in dust removal.

In normal operation dusty air enters the bottom of all tubes, passes up the inside, filters through the cloth, and leaves the compartment through the damper sections. During its 5.2 minute cycle, each section is simultaneously lifted and dropped in rotation while shut off from the fan and vented to atmosphere. The cleaning operation consists of four such raps with back-flow air. The compartment is replaced in service by shifting the damper automatically to its open position. In the test unit the total air flow to the fan is governed by the number of compartments filtering, and the amount of back-flow air entering when one section is cleaning.

B. Hersey Unit

The reverse-jet air filter consists of a cylinder of wool felt 18 inches in diameter connected to a top inlet plenum and a bottom hopper. Dust deposits on the inside of the cylinder and is blown into the hopper by a reverse-air jet from a slotted ring traversing the outside of the bag. Pressure drop through the bag controls cleaning action by regulating the amount of ring travel. (In many applications the ring runs all of the time). Fabric velocity varied from 10 to 30 cfm/sq.ft. Previous laboratory data reported (3) pressure drops from 1.0 inches water gage to 4.5 inches water gage on 1.0 grain/cu.ft. of fly-ash to 8.7 grains/cu.ft. of talc, respectively. Effluent loadings were in the range 10^{-3} to 10^{-5} grains/cu.ft. It was also reported that the intensity of reverse-jet action and filtration velocity both directly affect the effluent loading.

III. Performance Data

It is possible to compare pressure loss and penetration characteristics of the Entoleter and reverse-jet unit from tests at normal industrial operating conditions (Table I). Loadings range from 0.1 to 1.0 grain/cu.ft. with talc at filtration velocities of 7 and 8 cfm/sq.ft. and from 1.0 to

5.0 grains/cu.ft. with resuspended (Cottrell precipitated) fly-ash at 10 cfm/sq.ft.

A. Pressure Loss

In Table I, several comparisons may be made of pressure loss at constant inlet loading and filtration velocity. For example, in Test 1 the reverse-jet unit has a resistance of 1.6 inches water gage at 0.10 grain/cu.ft. of talc and in Test 2, the Entoleter unit has a resistance of 3.3 inches water gage at the same loading of the same material. The Entoleter resistance is double and the average ratio for all tests is 2.3 (same aerosol at constant loading). Although the reverse-jet unit has a wool felt bag which is higher in clean felt resistance, cleaning by a

TABLE I

Comparisons of Resistance and Effluent Loading for Hersey Reverse-Jet and Entoleter Bag Collectors

Test #		Aerosol	Capacity cfm/sq.ft.	Resistance iwg	Loading - gr./cu.ft. Inlet	Outlet	Passage %
1	Hersey*	Talc	8	1.6	0.10	0.011×10^{-3}	0.011
2	Entoleter	"	7	3.3	0.10	1.4×10^{-3}	1.4
3	Hersey	"	8	2.5	1.00	0.27×10^{-3}	0.027
4	Entoleter	"	7	4.7	1.00	2.1×10^{-3}	0.21
5	Hersey	Fly-ash	10	1.3	1.00	0.36×10^{-3}	0.036
6	Entoleter	"	10	3.1	1.00	2.2×10^{-3}	0.22
7	Hersey	"	10	1.6	5.00	0.80×10^{-3}	0.016
8	Entoleter	"	10	4.6	5.00	4.2×10^{-3}	0.084

* 100% Blow Ring Operation, Slot Velocity 2000 fpm talc, 4200 fpm fly-ash.

reverse-jet of air results in a lower operating resistance. The cotton sateen used in the Entoleter unit does not get the same degree of cleaning. The reverse flow air in the Entoleter amounts to a maximum of 300 cfm distributed over 100 square feet of cloth, or an average reverse air velocity of 3 fpm. It should be noted that the primary function of the reverse air in this device is to remove the suspended dust dislodged by rapping the bags and to prevent dust leakage to the clean air side of the unit. The reverse-jet operates in the range of 2000 to 4000 fpm over a very small area at any given time, but travels constantly over the whole filter surface.

If the Entoleter collector were operated at 3 cfm/sq.ft. as in usual bag filters, instead of 7 or 10, the resistance would be 2 to 3 times lower. For a given exhaust air volume this would require more collector area, but it would not require cleaning the bags as frequently to maintain a specified resistance.

In evaluating these collectors (both at maximum cleaning capacity) it may be noted that the reverse jet resistances are based on 100 percent blow ring operation. The Entoleter cleaning mechanism, however, operates only .40 minutes per section in 5.2 minutes total cycle and corresponds to 30 percent $\left(\frac{4 \times .40}{5.2} \times 100\right)$ operation. From NYO 1586, p. 26, Fig. 8, it is possible to estimate the additional resistance that would be required to operate the reverse-jet cleaning mechanism at 30 percent. This increase will be 25 percent if the 100 percent blow ring operation resistance is 5.0 inches water gage. With lower resistances as indicated in Tests 1, 3, 5, and 7 the increase is probably higher (up to as much as 50 to 75 percent for low resistances of 1.5 to 2.0 inches water gage). This will not cause the reverse-jet resistance to exceed that of the Entoleter, but will put them much closer together.

All resistances are expressed as averages. Some indications of the range associated with the average are included below. In test number 8 the Entoleter resistance is listed at 4.6 inches water gage. The average resistance or pressure drops across the four sections were respectively 4.2, 4.4, 4.7 and 5.0 inches water gage. Just before shaking Unit IV (highest) the value was 5.3; immediately after shaking the value dropped to 4.8 inches water gage. The average listed is the average of the four units (at equilibrium), each unit at its average operating resistance. In test number 7 the reverse-jet resistance is listed as 1.6 inches water gage. The variation in resistance during one cycle of the blow ring is from 1.6 (downstroke) to 1.7 inches water gage (upstroke).

B. Penetration

The amount of dust leaving the collector per unit air volume is also seen to be lower in the reverse-jet collector. The Entoleter (Test 1) effluent loading at .10 grain/cu. ft. inlet loading of talc is seen to be 1.4 grains/1000 cu. ft. of air, compared to 0.011 grains/1000 cu. ft. for the reverse-jet (Test 2) at the same inlet loading. The effluent loading from the Entoleter is 130 times higher. In tests 7 and 8 (5.0 grains/cu. ft. fly-ash) the Entoleter is only 5 times higher in effluent. On the basis of all the tests shown the Entoletor effluent exceeds the Hersey by a factor of greater than 5 when the inlet loading is less than 5.0 grains/cu. ft. At an average industrial loading of 1.0 grain/cu. ft. the factor is about 7 for both test dusts.

In filtration through porous materials the deposited surface dust cake is the principal filtering mechanism (8). In the reverse-jet unit this cake is dislodged at only a small area and the incoming dust can re-deposit immediately in this more porous area. (Some question exists as to how much of the deposited cake is removed). With the removal of large amounts of the surface cake in the Entoleter unit more time is required to create a layer over the larger cleaned area and penetration is higher. This would be particularly true under light loading conditions when insufficient material enters to "bridge" the spaces between fibers. With larger aerosol particles (>50 - 60 μ) the differences between these collectors may become less marked.

C. Evaluation of Different Bag Materials in the Entoleter Unit

As explained above in Section II, the Entoleter unit shakes the filter bags without appreciable distortion in conjunction with 100 to 300 cfm of back flow air, so that it is possible to use bags of materials other than cotton sateen with lower tensile strength, higher heat resistance, etc. The following table gives comparative data for cotton sateen, wool felt (light and heavy), Orlon (woven) and glass (woven, lubricated with silicone). These are compared for light loadings of atmospheric dust (0.5 μ) and copper sulfate (1 μ) without shaking, to get basic performance data. They are then compared with talc and resuspended fly-ash at an average loading of 1.0 grain per cubic foot to get an indication of actual industrial performance while cleaning on the standard cycle.

The approximate order of these fabrics for light loadings with no shaking, from highest efficiency is: glass, heavy wool, cotton, Orlon, and light wool. It can be seen that the higher efficiencies are associated with higher resistances. The use of heavy loadings changes the order slightly, from lowest penetration: glass, heavy wool, light wool, cotton and Orlon. A consideration of the smoothness of fiber, and weave (or felt) pore size, will tend to confirm the second list above, since the degree of deposited cake filtration depends on the character of the medium upon which the cake

TABLE II

Comparisons of Efficiency of Filter Media

Fabric	Average Resistance iwg	Inlet Loading gr/cu.ft.	Weight Efficiency %
	A. Atmospheric Dust at 10 cfm/sq.ft.		
Light Wool	0.07	0.10×10^{-3}	75
Orlon	0.10	0.13×10^{-3}	60
Cotton	0.29	0.15×10^{-3}	81
Heavy Wool	0.34	0.22×10^{-3}	85
Glass	0.56	0.058×10^{-3}	82
	B. Copper Sulfate at 10 cfm/sq.ft.		
Light Wool		0.89×10^{-3}	41
Orlon		0.81×10^{-3}	46
Cotton		1.0×10^{-3}	64
Heavy Wool		1.0×10^{-3}	71
Glass		0.90×10^{-3}	81
	C. Talc at 5 cfm/sq.ft.		
			Passage %
Light Wool	5.0	1.0	0.074
Orlon	5.5	"	0.033
Cotton	5.5	"	0.099
Heavy Wool	5.6	"	0.034
Glass	5.9	"	0.0063
	D. Fly-ash at 10 cfm/sq.ft.		
Light Wool	2.6	1.0	0.026
Orlon	2.4	"	0.56
Cotton	3.0	"	0.14
Heavy Wool	2.7	"	0.030
Glass	4.7	"	0.012

TABLE III

Fabric Comparisons
with
200 gr./sq.ft. of Asbestos Floats, at 10 cfm/sq.ft.

Material	Initial Resistance iwg	Final Resistance iwg	Passage %
Orlon	0.16	0.95	1.4
Cotton	0.36	1.4	1.1
Heavy Wool	0.36	0.90	0.72
Glass	0.81	2.2	0.40

is deposited, as indicated above (8) as well as the cake itself.

As stated before (NYO 1586, p. 47) the use of the above fabrics for low loadings (<0.001 gr./cu.ft.) of radioactive particulates would require many hundreds of hours of operation before filter efficiency increased to 90 percent or greater. Therefore, the above bags have been treated with asbestos floats as a filter aid and the efficiency again compared on copper sulfate. These data are given in Table III for a total of 200 grains of asbestos per square foot of filter surface. The bags were not shaken during the testing. The same order of rating of fabric is obtained as was found in Table II for the basic efficiency on copper sulfate. (The final resistance is not a direct measure of performance).

The use of asbestos "floats" and glass or Orlon bags can substantially increase the operating temperature limit for filtration of light aerosol loadings in the Entoleter collector.

IV. Conclusions

A comparison of the Entoleter collector with the reverse-jet filter at equal filtration velocities, dust loadings and with maximum cleaning capacity shows (Table I) that Entoleter penetration and resistance are on the average of 7.1 and 2.3 times higher, respectively. These data are based upon "standard" fabrics supplied for each unit; cotton for the Entoleter and wool felt for the reverse-jet unit.

With wool felt in both collectors, penetrations are found to be about equal for each aerosol tested. Resistances of the Entoleter, however, were found to be twice as high with fly-ash and 3.5 times higher with talc, as those of the reverse-jet filter.

The wool felt is concluded to be a better filter fabric than cotton sateen, at the same filtration velocity and the reverse-jet is found to be a superior method of cleaning wool felt.

The Entoleter unit offers the possibility of a wide choice of filter fabrics for special applications, chiefly synthetic fibers for corrosive problems, and glass fibers for higher temperature applications, subject to field service life tests not possible to accomplish in the laboratory.

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